ENVIRONMENTAL PROTECTION IN AUTOMOTIVE INDUSTRY

Dušan Gruden 1PhD, Professor

UDC: 504.054;67.017

INTRODUCTION

Scientists claim that 1.000 billion (1012) galaxies exist in continuously expanding cosmos. One of these galaxies, “The Milky Way”, contains 100 trillion (1020) stars. Among this infinitely large number of heavenly bodies, there is Earth, the planet we live on. Oxygen content of 21% in Earth's atmosphere, ¾ of Earth's surface under water and the difference between maximal and minimal temperatures on Earth's surface atmosphere amounting to 100°C (from -50°C to +50°C), have enabled life on Earth as we know it.

Despite the conviction of men, that we are very developed civilization, with almost unlimited possibilities of technology, man has not been able to prove that there is any other life in the rest of the universe. In other words, we are on our own in the infinite space. Planet Earth, with its many different forms of life, the rarity of the cosmos, must be preserved. That is primary obligation of the mankind, with all its possibilities.

For people from the ancient times, the world consisted of four elements: air, water, earth and fire. Although a modern man of the 21st century knows over 110 chemical elements, activities in contemporary environmental protection are focused precisely on these four elements, because all living beings on this planet need air, water and land for their existence. Clean air and clean water are prerequisites for living.

Prometheus was punished by the gods, because he allowed the people the use of fire, which had previously been the exclusive privilege of the gods. Mastering and using fire are the fundamental events that have provided people with evolutionary path of development, up to modern homo sapiens.

Despite the progress of modern man, one thing has not changed. In today's world, the four ancient elements are also of great importance. The further fate of the planet is becoming increasingly dependent on the kind of care we give to these elements and their remaining reserve. The four ancient elements must be protected and preserved:

Air: by continuing the reduction of exhaust emissions.

Water: by protecting it from the impurities and harmful sediment.

Earth: by reducing the amount of disposed waste and by rational use of its remaining reserves.

Fire: by better understanding of combustion process in engines and other technical processes and by increasing their efficiency.

Increase of the standard of living for many people has been achieved for the first time in the last century without the exploitation of other people, by using the technics and by exploitation of natural resources.

"Acid rain", "ozone hole", "forest decay" and "climate catastrophe", despite the excessive dimensions in which they are presented to the public, are still the warning signals that should not be ignored, because the over-exploited nature can perform its revolution, as well as over-exploited man. Only, by revolution of nature, all problems of mankind would have been irrevocably settled, once and for all.

1 Dušan Gruden, TU Wien, Austria, Ditzingen, email:gruden@yudit.de

Is there a possible way out of this situation? Can we find solutions that will save the lives of all beings on this planet and allow further development of mankind? A huge moral responsibility for finding the answer to this question is laid upon us, the engineers.

Our technology is based on physical laws - the laws of nature. We just have to learn to use these laws in the technical products not against, but in cooperation and in accordance with nature. This is the one of the main challenges today. In order to survive, we must learn the motto: "A man and technology in harmony with nature".

VEHICLE AND HUMAN ENVIRONMENT

Motivated by his natural instincts: altius, citius, cellerius (higher, faster, further), a man was trying to increase the speed of his movements from his beginnings, in order to increase his mobility. Since the beginning of the so-called "Industrial Revolution", which began with the invention of the steam engine in the late 18th century, the image of nature is has changed significantly. The influence of man was particularly obvious in the crowded populated regions, where many plant and animal species were gone forever. Thus, the industrial revolution led to environmental disasters in many places.

With the invention of motorized vehicles in the late 19th century, men were provided with means to quickly and easily get to desired destination at any time. The vehicle was one of the inventions that have greatly contributed to the high standards of modern people and has become an inseparable part of modern society and of the economic system. Over 800 million passenger vehicles worldwide, over 99% of them driven by IC engines, are compelling evidence of need and desire for the vehicle.

Each year, about 70 million vehicles are produced the world (Fig. 1)

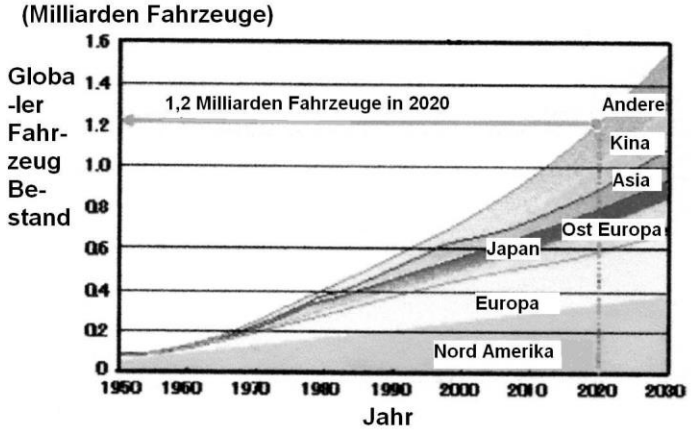


Figure 1 Vehicle manufacturing worldwide

This mass motorization has become a problem, because motorized traffic has become an important source of various impacts on the environment. It is one of the largest consumers of energy and a major source of unwanted exhaust emissions.

During the last decades, knowledge has been crystallized that the impact of vehicles on environment can be divided into:

Local impact: mainly in populated areas - emissions of carbon monoxide (CO), unburned hydrocarbons (HC), nitrogen oxides (NOx), particulate matter (soot, PM), noise and the like.

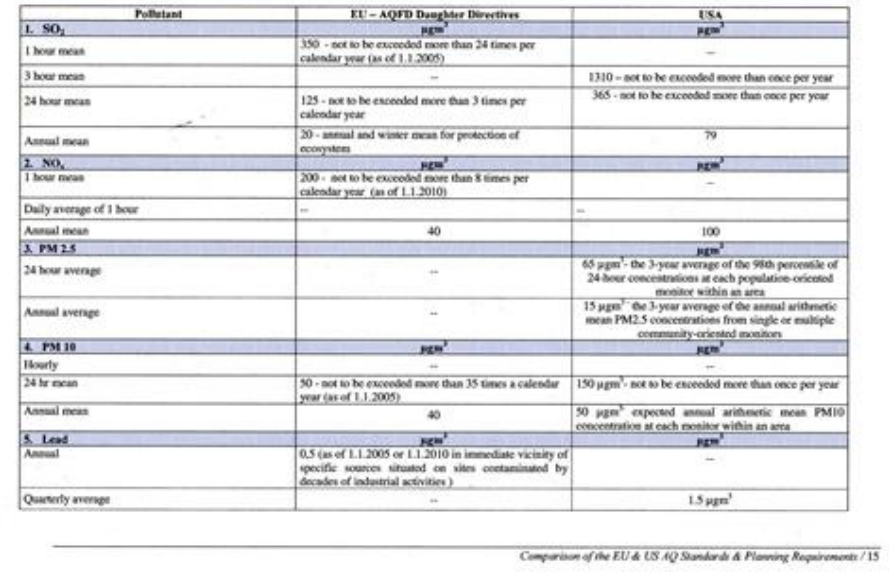
Regional impact: like "acid rains", "ozone smog", "forest decay", as well as the growing waste landfills and pollution of water and soil.

Global impact: usually registered in discussions on climate change, global warming, "ozone hole" and excessive exploitation of natural resources of energy, raw materials and food.

Concern about the impact of human activity on nature is not a new phenomenon or a new feature of the modern man. There is a new dimension of the efforts made to protect the environment.

In the early 1970s, after nearly a hundred years of vehicle development, the vehicle's "eco-development" had started in order to reduce the negative impact of vehicles on nature and environment. The last third of the previous century will go into history as the phase of significant increase in responsibility of all industries in protecting the environment.

Although there has been much talk about air pollution in public, it took several decades before the European experts agreed on air quality that is required for a healthy life of humans, animals and plants. In the USA, the National Ambient Air Quality Standards (NAAQS) were adopted already in 1970 and were revised in 1985. European air quality standards were introduced at the beginning of this century (in 2005) and revised in 2010 (Fig. 2).



Pollutant	EU – AQFD Daughter Directives	USA
1. SO_2	**$\mu g m^{-3}$**	**$\mu g m^{-3}$**
1 hour mean	350 - not to be exceeded more than 24 times per calendar year (as of 1.1.2005)	--
3 hour mean	--	1310 – not to be exceeded more than once per year
24 hour mean	125 - not to be exceeded more than 3 times per calendar year	365 - not to be exceeded more than once per year
Annual mean	20 - annual and winter mean for protection of ecosystem	79
2. NO_x	**$\mu g m^{-3}$**	**$\mu g m^{-3}$**
1 hour mean	200 - not to be exceeded more than 8 times per calendar year (as of 1.1.2010)	--
Daily average of 1 hour	--	--
Annual mean	40	100
3. PM 2.5		**$\mu g m^{-3}$**
24 hour average	--	65 $\mu g m^{-3}$ - the 3-year average of the 98th percentile of 24-hour concentrations at each population-oriented monitor within an area
Annual average	--	15 $\mu g m^{-3}$ - the 3-year average of the annual arithmetic mean PM2.5 concentrations from single or multiple community-oriented monitors
4. PM 10	**$\mu g m^{-3}$**	**$\mu g m^{-3}$**
Hourly	--	--
24 hr mean	50 - not to be exceeded more than 35 times a calendar year (as of 1.1.2005)	150 $\mu g m^{-3}$ - not to be exceeded more than once per year
Annual mean	40	50 $\mu g m^{-3}$ - expected annual arithmetic mean PM10 concentration at each monitor within an area
5. Lead	**$\mu g m^{-3}$**	**$\mu g m^{-3}$**
Annual	0,5 (as of 1.1.2005 or 1.1.2010 in immediate vicinity of specific sources situated on sites contaminated by decades of industrial activities)	--
Quarterly average	--	1.5 $\mu g m^{-3}$

Comparison of the EU & US AQ Standards & Planning Requirements / 15

Figure 2 Air quality standards in the EU and the USA

Although modern vehicles are far better in terms of environmental characteristics than their predecessors from 30 or 20 years ago, they are still far from satisfactory, in public opinion.

Reduction of emission of carbon dioxide (CO2) and other emissions that are considered the cause of climate change is at the centre of the current environmental policy. Reduction of harmful exhaust emissions, fuel consumption and CO2 emissions follows the development of vehicle and its power unit - IC engine for decades.

ENVIRONMENTAL LAWS FOR AUTOMOTIVE INDUSTRY

Protection of the environment was declared as objective of national priority in many industrially developed countries. It stands as an equal category with classic objectives such as the preservation of peace, employment, economic growth and monetary stability

As the first measure, the legislation introduced the two categories of limit values for harmful air components.

The first category relates to the air quality at the workplace. In the European Union (EU), so called "Binding Limit Values" are valid, which are mandatory for all EU member states. Several hundred substances are included on this list (Regulation 67/548/EWG or EC 2008/1272 - Regulation on classification, labelling and packaging of substances and mixtures). This list replaces the former list of Maximum concentrations at the workplace (MAK).

The second category relates to the quality of the outer air. EU directives on "Ambient air quality and cleaner air for Europe" (2008/50/EC) and "National emissions ceilings for certain pollutants" (2001/81/EC - NEC Directive) provide immission limit values for a number of substances that occur frequently and can be harmful to health. Since January 1st, 2010, these limits may not be exceeded (Table 1).

Table 1 Immission Limits for individual components in the EU and proposal of the World Health Organization (WHO)

	2008/50/EC	WHO	
Carbon monoxide (CO), mg/m3	10	10	8h mean value
Nitrogen oxide (NO2), µg/m3	40	40	annual mean
Particles PM10, µg/m3	25	20	annual mean
Particles PM2,5 , µg/m3	25	10	annual mean
Ozone (O3), µg/m3	120	100	8h mean value
Benzene (C6H6), µg/m3	5	5	annual mean
Led (Pb), µg/m3	0,5	0,5	annual mean
Sulphur dioxide (SO2), µg/m3	50	20	annual mean

Further legislation limit the noise exposure (Regulation 86/188 / EEC - Protection of workers from exposure to noise at work) not only at the workplace, but also in everyday life (2003/10/EC - The minimum health and safety requirements (noise)).

Legislations regarding environmental protection guarantee the certainty that the prescribed imission values would be fulfilled.

Since the beginning of the 19th century, when first negative impacts of industrial production on nature were noticed, the number of regulations regarding environmental protection has been constantly increasing. Meanwhile, so many regulations have been created, that even the experts who deal with them, find it difficult to follow the development in this area.

REGULATIONS IMPORTANT FOR AUTOMOTIVE PRODUCTION

An important moment in European legislation in the field of environmental protection is the adoption of directive on Integrated pollution prevention and control (96/61/EC - IPPC).

Anyone who develops, produce, processes and sells products, carries a responsibility to meet all the standards of environmental protection.

The enforcement of the directive 2010/75/EC (IED - Industrial Emission Directive) is at the centre of activities, and it requires, among other things, the description of the current situation in emissions of all environmentally relevant production processes.

Water protection is regulated by laws, regulations and ordinances. In year 2000, the EU adopted a directive 2000/60/EC - Water Framework Directive on quality of wastewater.

European directive 75/442/EC - Waste Framework Directive (WFD) of 15 January 1975 has been the basis of European policy towards waste since January 15th, 1975. Since 2008, it regulates the waste treatment of industrial plants (2008/98/EC). Directive 91/156/EC (Directive on hazardous waste) defines as waste all which cannot be defined as a product.

Law on Chemicals should protect the environment from harmful effects of toxic substances. European directive REACH (Registration Evaluation and Authorization of Chemicals, 1907/2006/EC), which has been in force since 2005, provides strict control over those substances which may have a negative impact on health and environment. Since November 2011, the Law on classification of chemicals (1272/2008 / EC) has been in effect. This law and REACH regulation are the basis for safe use of chemicals in production.

Regulation on information related to environmental protection (2003/4/EC, Public access to environmental information) should facilitate a public access to information about the state of water, air, noise, soil and flora and fauna in the vicinity of industrial plants.

Regulations important for vehicle homologation

The technical development of vehicles today is unthinkable without taking into account the strict regulations. Fig. 3 shows an example of legislation that a vehicle must meet before it has been released to the European market. Only by satisfaction of these regulations a license for sharing the market is obtained. Part of these regulations applies to the ecological characteristics of a vehicle.

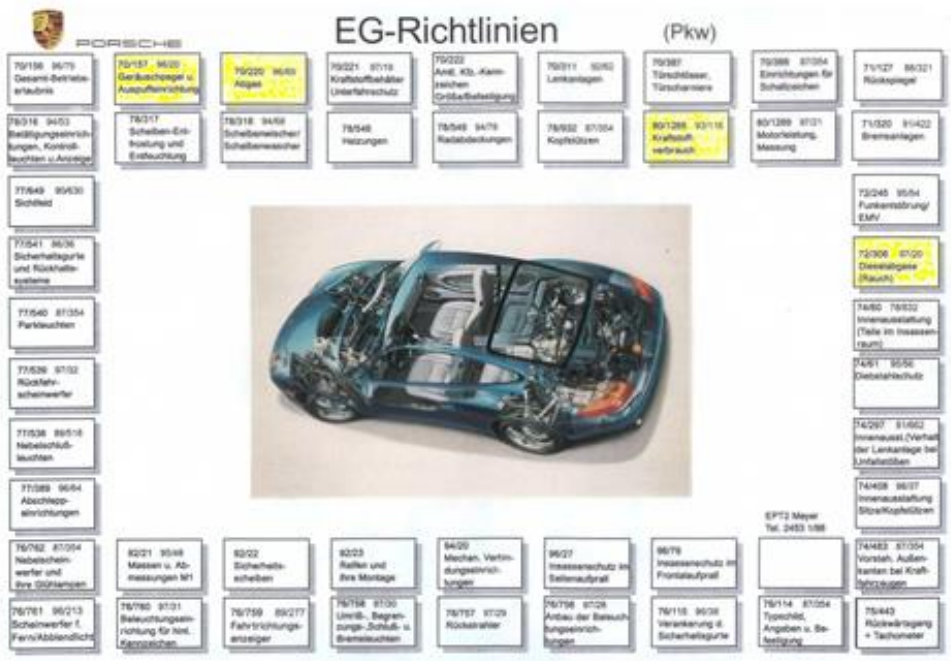


Figure 3 Regulations concerning vehicle registration

Similar, but not the same requirements exist in the United States, Japan, Australia and other countries.

EXHAUST EMISSION

The first legislation on the limitation of exhaust emissions from passenger vehicles were passed in California, in 1966. They have a pioneering role in the development of the vehicles in all the countries of the world. Nearly over the past 50 years, they have evolved considerably in their shape, complexity and application areas.

The first directive on limitation of exhaust emissions of passenger vehicles in Europe was adopted in 1970 (Directive 70/220/EC). Since then, it has been changed ten times and is obligatory for all EU member states.

Directive 98/69/EC defines limit values for the following components of the exhaust emissions of Otto and Diesel engines:

- Carbon Monoxide (CO)
- Unburned hydrocarbons (HC)
- Nitrogen oxides (NOx)
- Solid particles and soot, particulate mas (PM) and particulate numbers (PN)

With the application of Directive 75/2007/EC, a request for further reduction in emissions is set in the EU through so-called Euro 5 and Euro 6 limit values (Table 2 and Table 3).

Table2 EU - Exhaust Emission Limits for passenger vehicles with gasoline engines

Introduction year		CO					
[g/km]	THC						
[g/km]	NMHC						
[g/km]	NOx						
[g/km]	PM						
[g/km]	PN [N/km]						
2000	Euro 3	2,3	0,2	-	0,15	-	-
2005	Euro 4	1,0	0,1	-	0,08	-	-
2009	Euro 5	1,0	0,1	0,068	0,06	0,0045	-
2014	Euro 6	1,0	0,1	0,068	0,06	0,0045	6x1012

Table3 EU - Exhaust Emission Limits for passenger vehicles with diesel engines

Introduction year		CO				
[g/km]	HC+NOx					
[g/km]	NOx					
[g/km]	PM					
[g/km]	PN [N/km]					
2000	Euro 3	0,64	0,56	0,50	0,05	-
2005	Euro 4	0,50	0,30	0,25	0,025	-
2009	Euro 5	0,50	0,23	0,18	0,0045	6x1011
2014	Euro 6	0,50	0,17	0,08	0,0045	6x1011

Starting with Euro 4 regulation, all parts of the vehicle that affect exhaust emissions must prove their useful lifetime for 100.000 km, and starting from Euro 5 regulations, their lifetime was extended to 160.000 km.

Situation in the field of legislation in the United States has become difficult to overview due to the parallel legislations in California and 49 other states, but also due to many special rules and extensive lists of possible combinations.

In September 1990, the California Air Resource Board (CARB) has adopted a program called "Low Emissions Vehicle Regulations" (LEV). This program demanded continual introduction of a growing number of "clean vehicles" to market by the automotive industry, with continuous exhaust emissions control (On Board Diagnose, OBD). For the first time, four categories of vehicles were introduced which had to continuously meet the increasingly stringent legislation:

- TLEV - Transient Low Emissions Vehicles (since 1995)
- LEV - Low Emissions Vehicles (since 1988)
- ULEV - Ultra Low Emissions Vehicles (1998)
- ZEV - Zero Emissions Vehicles (2% by 1998, 10% since 2010)

Since the demand for ZEV could not be reached until today, the law had adopted LEV II regulation in 1998, which introduced two categories of vehicles:

- SULEV - Super Ultra Low Emissions Vehicles and
- PZEV - Partial Zero Emissions Vehicles.

New LEV III regulation was adopted in 2012, which tightens the limits for HC, NOx and PM, and applies to all vehicles from 2020.

In almost all modern countries of the world, regulations on limitation of exhaust emissions are in force and are based on the legislations of the European Union, the United States or the laws of Japan (Fig. 4).

There is a common principle that the tests are carried out on the test bench and that they have their own, specifically prescribed pattern of driving. Differences in testing methods in the EU, USA, Japan, are increasing significantly the cost of development and homologation for producers who offer their vehicles to the global market.

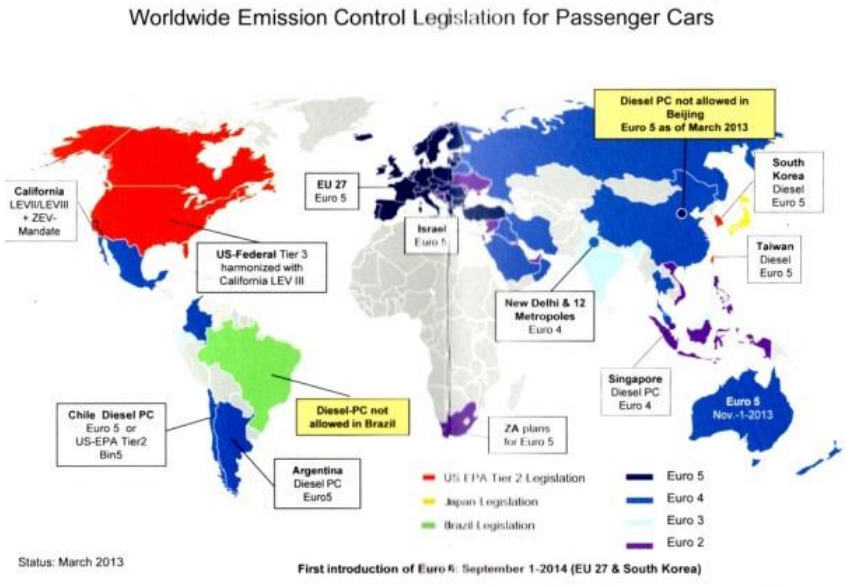
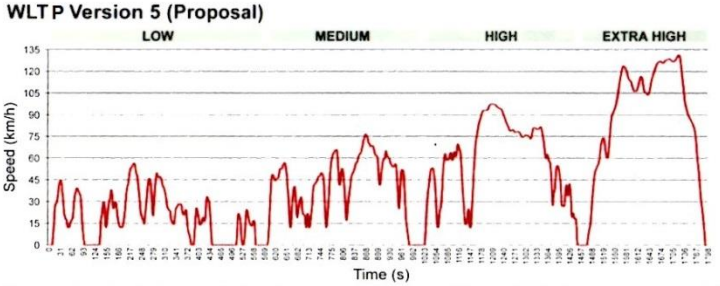


Figure 4 Exhaust Emission Regulations worldwide

Desire to create the world's uniform, joint regulations penetrates very slowly the awareness of legislators. The first goal is to consent to a harmonized, valid for the whole world test for determination of vehicle exhaust emission and determination of vehicle's safety. For years, there is a proposal for a unique cycle for determination of emissions, so called World Light Duty Test Procedure (WLTP) (Fig. 5).



	NEDC [1)]	WLTC
Length (s)	1.220	1.800
Length (km)	11,06	23,26
Idle time (%)	33	13
V_{max} (km/h)	120	131,6
$V_{average}$ (km/h)	31,6	46,3
$Accel_{max}$ (m/sec^2)	1	1,6

[1)] NEDC = New European Driving Cycle - ECE + EUDC

Figure 5 World Light Duty Test Procedure (WLTP, proposal)

FUEL CONSUMPTION AND CO2 EMISSION

Fuel consumption is measured in parallel with the measurement of emissions.

In the EU, fuel consumption is not directly limited, but, since 1978, the manufacturers are required to provide information on the amount of fuel consumption. The fuel consumption is indirectly limited through CO2 emissions. Between CO2 emissions and fossil fuel consumption (B) there is the following dependency:

- CO2 = 24 x B [l / 100 km] for vehicles with spark-ignition engine,
- CO2 = 27 x B [l / 100 km] for vehicles with diesel engines.

With regulation 443/2009 EC, the average CO2 emission of a manufacturer's fleet must be reduced to 120 gCO2 /km (about 5 l / 100 km) from 2012 to 2015. Until 2021, this value must be reduced to an average of 95 gCO2 / km (approximately 3,5 - 4,0 l / 100km) (Fig. 6).

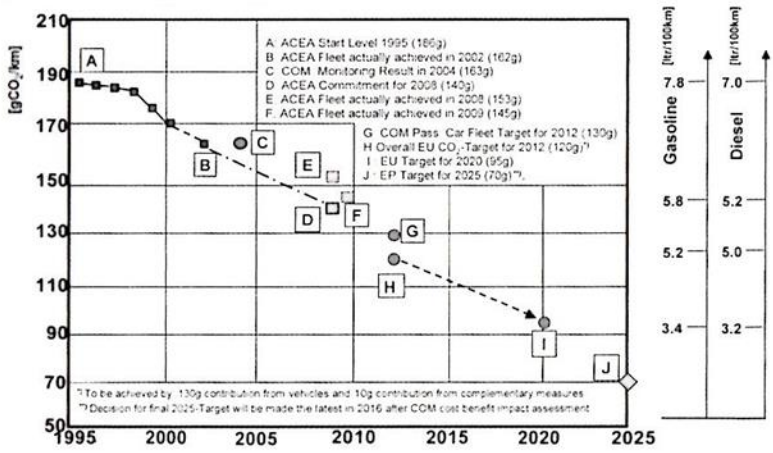


Figure 6 Reduction of CO2 - Emissions and fuel consumption in the EU

In the United States, the fuel consumption was limited to 27.5 mpg (8.55 l / 100 km) by so called CAFE standard (Corporate Average Fuel Economy) since 1978. In 2010, the United States adopted new rules for fuel consumption and CO2 emissions. Limit values for fuel consumption and CO2 emissions depend on the so-called "Footprint" or geometrical area of the vehicle (Fig. 7).

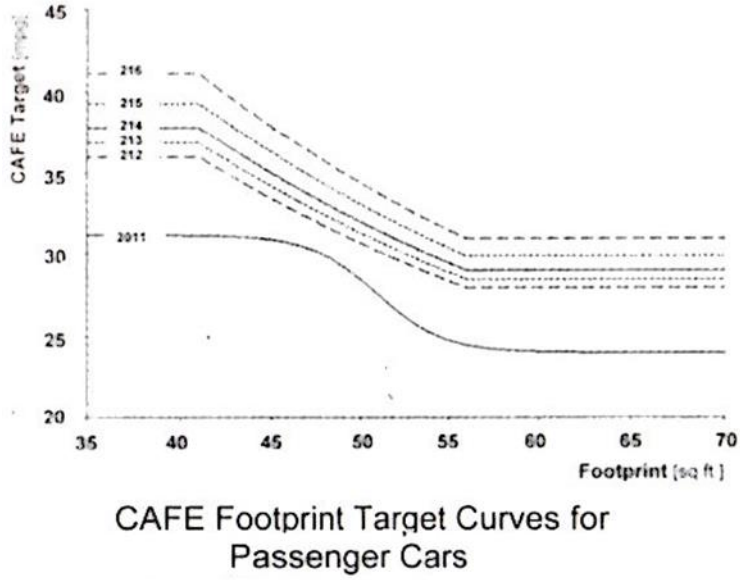


Figure 7 CAFE footprint target for fuel consumption

VEHICLE NOISE

In the EU, regulation 70/157 / EC on the limitation of noise of passenger vehicles applies since 1966. At regular intervals, permitted noise of the vehicle has been reduced from 84 dB(A) to currently valid 74 dB(A). In addition to the first source of noise, the

engine and transmission, other relevant sources have been observed: aerodynamics, tires, road condition, etc. One of the proposals in the EU is to reduce tire noise to

- 72 to 76 dB(A) for passenger vehicles and
- 76 to 79 dB(A) for commercial vehicles.

Vehicle stationary emissions

In order to reduce the overall emissions of unburned hydrocarbons emitted by a single vehicle, HC-emissions of a parked vehicle, resulting from evaporation of fuel, rubber, plastic and various adhesives, must also be taken into account.

Since 1983 in the United States and since 1993 in the EU, tests of vaporization of hydrocarbons of the entire parked vehicle have been effective, which are carried out in special chambers called SHED-test chambers (Sealed Housing for Evaporate Emission Determination) (Fig. 8).

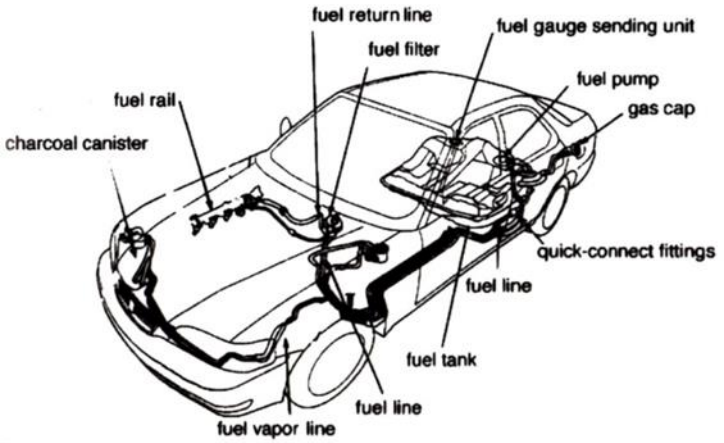


Figure 8 Source of the evaporative loses in a vehicle

ENVIRONMENTAL PROTECTION ACTIVITIES IN AUTOMOTIVE PRODUCTION

Automotive production is associated with the consumption of raw materials, energy, water and air. In addition to the desired product - vehicle, there are side effects like the resulting exhaust gases, excess heat, waste water and other waste.

Impact on the environment (air, soil, water) during production has not yet been possible to avoid, but, today, the development of a product without considering its environmental impact on the entire journey from "cradle to grave" is no longer possible. Since the beginning of the 1980s, regulations on environmental protection during production have continually been tightened.

ENERGY CONSUMPTION

According to data of different manufacturers and depending on the size of the motor vehicle, vehicle production consumes about:

1.6 to 7.2 MWh per vehicle

out of which, approximately:

0.4 to 3.2 MWh of electricity and

1.0 to 4.5 MWh of thermal energy.

During vehicle lifetime, about 10 to 15% of the total consumed energy is spent on vehicle production. In this, the largest consumer of energy is vehicle paint coating process. As energy costs account for about 30% of the vehicle production costs, the energy saving is one of the main aims not only in protection of the environment, but it also affects the reduction of production costs.

EXHAUST EMISSION

Modern vehicle production is still accompanied by the exhaust emission. The following emissions are formed during vehicle production:

- Carbon monoxide (CO), 0.2 - 1.7 kg/vehicle
- Nitrogen oxides (NOx), 0.3 - 0.8 kg/vehicle
- Sulphur dioxide (SO2), 0.0 - 0.8 kg/vehicle
- Solid particles, soot (PM), 0.05 - 0.3 kg/vehicle
- Organic substances (VOC), 1.0 - 7.9 kg/vehicle
- Carbon dioxide (CO2), 1.0 -1.7 t/vehicle

Since 2005, the industrial plants with power greater than 20 MW must seek permission for the maximum permitted amount of CO2 emission.

Since September 1987, 87 world countries have signed the so-called "Montreal Protocol", which prohibits the use of fluorine-chlorine-hydrocarbons (FCHC), which are considered to endanger the ozone layer in the stratosphere. In air conditioning systems, FCHC were first replaced with R134a agent, which is not harmful to the ozone layer. But, as R134a has a greenhouse effect (Global Warming Potential, GWP of 1430), its use is prohibited by directive 2006/40/EC from January 1st, 2011. Instead of it, agents R-1234yf (GWP=4.0) and R744 (CO2, GWP=1.0) are being tested.

Large environmental loads were noted during application of solvents based on hydrocarbons in the process of vehicle painting. Application of paints based on water solvents or based on powder (without solvent) and investments in new paint shops, have contributed to significant reduction in HC emissions in vehicle production (Fig. 9).

Figure 9 Reduction of the VOC emission of German automotive manufacturer

WATER CONSUMPTION

Relatively large amounts of water are used during vehicle production:

- 2.3 to 8.0 m3/vehicle in the production of passenger vehicles.

Therefore, the rational use of water is one of the important aspects of environmental protection.

In modern vehicle production, water is recycled and repeatedly applied. Every litre is used up to 120 times again, before it has been purified and released to sewage.

WASTE

Passenger vehicle production is accompanied by approximately 60 different types of waste. All waste must be included in the so-called "roundabout" (recirculation) of waste. Therefore, it is necessary to selectively collect waste directly at the source.

The amount of waste generated in the passenger vehicle production share is:

- 35-150 kg/vehicle of industrial waste and waste similar to household waste and
- 0.5 to 15 kg/vehicle of water treatment waste (sediment, sludge).

European Waste framework directive (2008/98/EC) defines only two types of waste:

- waste for recovery and
- waste for disposal.

Main objective of ecological waste treatment is to reduce its quantity. True engineering solution is so-called "Technical waste reduction", which is achieved by the inclusion of ecological thinking in the planning, design and development of products (so-

called "Design for environment"). The ideal goal of ecological production is “Zero emission and waste production”.

ENVIRONMENTAL AUDIT

Control the organizational and technical measures in the field of environmental protection in the vehicle production is done through so-called environmental auditing. European Union directives 1836/93/EC and 1221/2009/EC speak of "voluntary participation of organizations in the common system for environmental management and environmental protection control". These directives are known as EMAS - "Eco Management and Auditing Scheme". In the foreground, there are "prevention, reduction and, if possible, avoidance of impacts on the environment, possibly already at the source, as well as the rational use of resources of raw materials and the use of clean technologies."

EMAS represents a comprehensive survey of the environmental situation of enterprises and assessment of the ecological status and its impact on the environment (Fig. 10).

The main element of the regulation on environmental auditing is to create a system of environmental management. This system should help the company to improve its efforts in the field of nature protection during the entire life of the vehicle.

Prerequisite for creation of ecological management is the integration of the idea of protecting the environment into general goals and policies of the company. This system must include all parts of the company: research, development, procurement, production, sales, personnel department, finance department, quality control, work safety, etc. System for environmental protection must provide the fulfilment of all legal requirements and its own set of environmental goals.

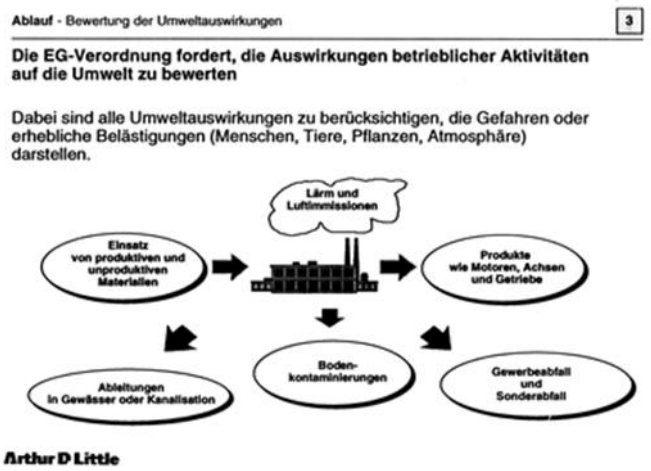


Figure 10 EMAS: Impact of corporate activities on the environment

In accordance with EMAS, companies are required to document their organization and activities in the field of environmental protection, at all levels. The regulation prescribes the exact method of auditing. The final process of eco-auditing is the publishing of "Environmental Report", which is checked by a neutral experts, whether the whole procedure corresponds to the European regulations. Based on the positively estimated "Environmental report", the company is entered into the eco-register and gets

"Environmental certificate." The once obtained certificate is not valid forever, but must be renewed every third year.

Table 4 EMAS and ISO 14000

Criteria	EC – eco audit	ISO – Norm 14001
Application	All organization wishing to an environ-mental-oriented leadership	For companies of any kind and parts thereof, not location related
First environmental assessment	required	Recommended
Review of the environmental management System	Comprehensive environmental review required every 3 years	Regular auditing prescribed , bat without Absolute time schedule
What is covered?	All environmental-related activities, products and services	Environmental aspects that appear to be controlled
Continuous improvement	The corporate environmental protection in terms of reducing environmental impact	Of impacts on the environment
Technical measures	Application of "best available, commercially reasonable technology" to reduce the environmental impacts	Taking into account "technical options"
Environmental Report	Must be created and declared valid	Not required
Verification/acceptance	Assessment with participation statement	Certification/Certificate
Make public	Obligation to publish the environmental report	Obligation to publish the environmental policy
Worldwide	Across the EU, regulated by law, includes rules for authorization procedure for environmental experts	Worldwide

Regulation EMAS is not the only possible control of environmental measures. All organizations have a choice between the European EMAS regulations and international standard ISO 14001. Table 4 shows the similarities and the differences between these two systems of environmental auditing.

Organization of management of environmental protection system is similar to the organization of management of quality control.

TECHNICAL MEASURES FOR REDUCTION OF EMISSIONS FROM OTTO AND DIESEL ENGINES

Despite the intensive efforts and numerous attempts to find another power drive for motor vehicles, IC engine has remained the undisputed power drive, not only for vehicles, but also for many other application areas. For almost 140 years, Otto and Diesel engines

show that they are the best response of engineers to offer of so far the most comfortable and the cheapest energy source - oil. No other power unit has so far succeeded to use the energy contained in fossil fuels with such high efficiency.

Both engine versions will retain its importance as power units of motor vehicles for the foreseeable future. This means that the development in terms of reducing the fuel consumption and exhaust emissions will be intensively continued.

In addition to the theoretically comparative Otto and Diesel engines cycles, which take into account only the engine's economy, a new theoretical cycle was patented in 1975, which takes into account the reduction of exhaust emissions (HC and NOx) - the so-called thermodynamic cycle with isothermal expansion, as shown in Figure 11.

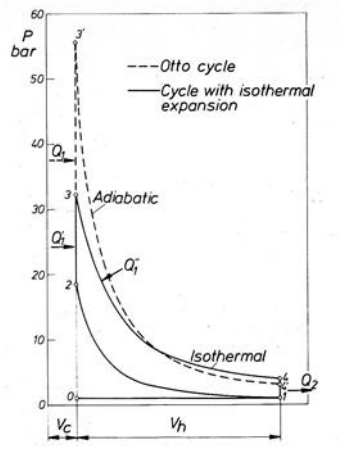


Figure 11 Otto cycle and thermodynamic cycle with isothermal expansion

It has been established that modern Otto and Diesel engines with multiple direct injection work according to this cycle.

Since the first introduction of legislation on the restriction of exhaust emissions in the early 1970s, for the existence of engines it is crucial for them to meet all the existing and planned regulations on the reduction of negative environmental impact. Otto and diesel engines have shown incredibly great potential for development, which had provided their inviolability up until today. Measures for minimum exhaust emissions and reduction of fuel consumption (and, hence, CO2 emissions), include optimization of a large number of parameters and systems. The most important of them are summarized in Tables 5 and 6.

Table 5 Measures to reduce „Raw" emission in the cylinder

Measures to reduce "Raw" emission in the cylinder

Gasoline engine	Diesel engine
A. Operating parameters	***A. Operating parameters***
• mixture formation system	• air mixture, swirl
• control of mixtures into each cylinder	• injection pressure (> 2.000 bar)
• optimization of the ignition timing	• moment and law of injection
• precise exhaust gas recirculation	• precise exhaust gas recirculation
	• charging with cooling of intake air
B. Design parameters	***B. Design parameters***
• compression ratio	• 4 valves per cylinder
• piston diameter and stroke	• combustion chamber shape
• variable intake system	• compression ratio
• variable valve timing	• location of the injector
• minimization of dead spaces in the combustion chamber	• minimization of dead spaces in the combustion chamber
• Reduction mechanical losses	• Reduction mechanical losses

Table 6 Reduction of emission in the exhaust system

Reduction of emission in the exhaust system

Gasoline engine	Diesel engine
• installation of 3-way catalyst near the engine	• oxidation catalyst
• reduction of heat capacity of exhaust system	• reduction catalyst
• two λ – probes per catalyst	• selective catalyst
• thermally well insulated exhaust system	• NOx – absorption catalyst
• controlled introduction of secondary air	• Particulate filter
• possible electric preheating of the catalyst	• particulate filter with continuous regeneration

In addition, all vehicles must have a tank with active carbon to reduce evaporation from the stationary vehicle, as well as a complete system for controlling exhaust emissions during exploitation (OBD).

Discussion on the impact of CO2 emissions on possible climate changes has particularly intensified the efforts to reduce the fuel consumption, which follow the development of the engine from the very beginning. Development of new materials, the use of new production technologies and control and management of engine processes, constantly open new ways to reduce fuel consumption.

Vehicle noise

Among all the negative impacts on the environment, vehicle noise represents the most sensitive problem. The engine exhaust system has a special role in this, where specific task is the integration of the catalytic converter and muffler. Complex exhaust systems of modern vehicles require careful development, as well as all other systems for noise reduction and isolation (Fig. 12).

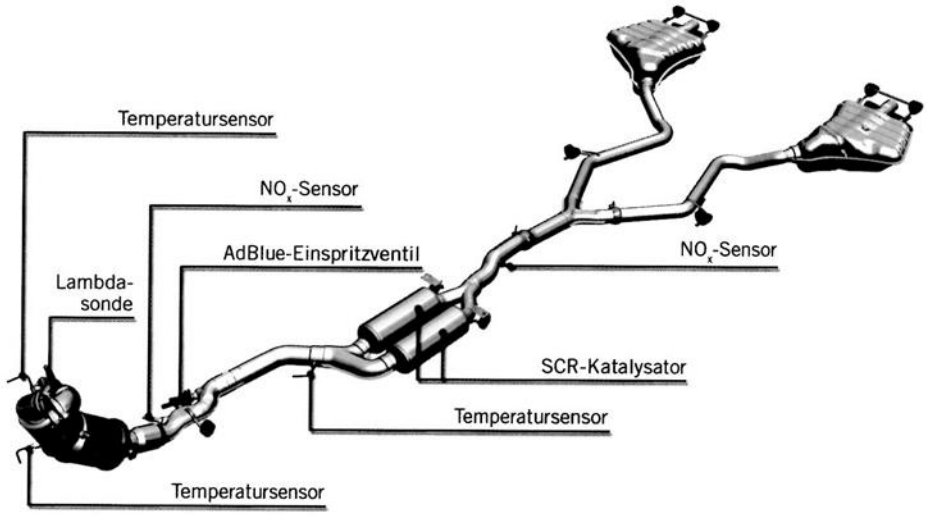


Figure 12 Modern engine exhaust system

IMPORTANCE OF FUELS

Solution to the problem of "Impact of vehicles on the environment" cannot be found only at the development departments of the automotive industry. A significant part of the solution is found at producers of energy or fuels for vehicle engines. Because "clean" engines require "clean" fuels. Therefore, the cooperation between the oil and automotive industries is of particular importance.

Opportunities provided by new engine concepts and new technologies for exhaust gases after treatment, can be fully used only if the whole system is optimized. Fuel, as an important part of the engine, must be included in the system optimization.

Major global automotive producers have set requirements that fuels must meet in order to be successfully applied in modern engines at the so-called "World Wide Fuel Charter". After the elimination of lead, reduction of the amount of aromatics, especially benzene, attention was paid to the reduction or complete removal of sulphur from the fuels, because the least amounts of sulphur have negative effect on the operation of the system for the exhaust gases treatment.

VEHICLE IN TRAFFIC

When a new vehicle has successfully passed all the homologation tests and is put into traffic, the public begins to detect all positive and all negative vehicle features.

Directive on consumer information requires that consumers must be informed on fuel consumption and CO2 emissions when vehicle is sold, because they can influence the decision to purchase the vehicle (Fig. 13).

Vehicle exhaust emissions and noise are controlled during the specified vehicle lifetime. Producers have to guarantee that their vehicles meet the exhaust gas regulations during the lifetime of 160.000 km (EU Regulation from 2010).

In the first place, there is the reduction of evaporative emissions of fuel in transport, during pump station supply and during refuelling of the vehicle tank (Fig. 14).

Control of vehicle exhaust emission in traffic is done by so-called On Board Diagnostics (OBD), which was first introduced in the USA in 1994 and in Europe since

January 1st, 2000. OBD provides continuous electronic control of all vehicle parts relevant for exhaust emissions.

If any of the systems is not operating, the so-called MIL (MIL - Malfunction Indicator Lamp) lights up on the dashboard of the vehicle. Despite the presence of the OBD, in many countries, it is biannually checked by special examination (AU - Abgasuntersuchung) weather the engine is tuned according to the producer's regulations.

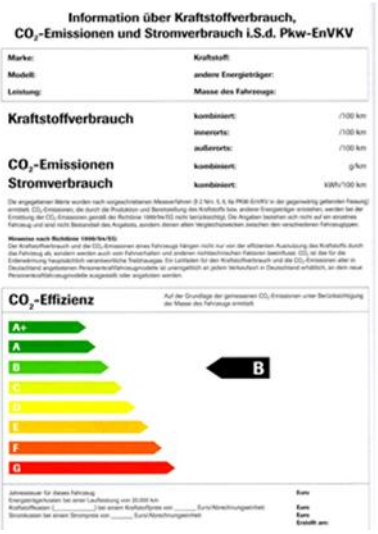


Figure 13 Information on fuel consumption and CO2 emission

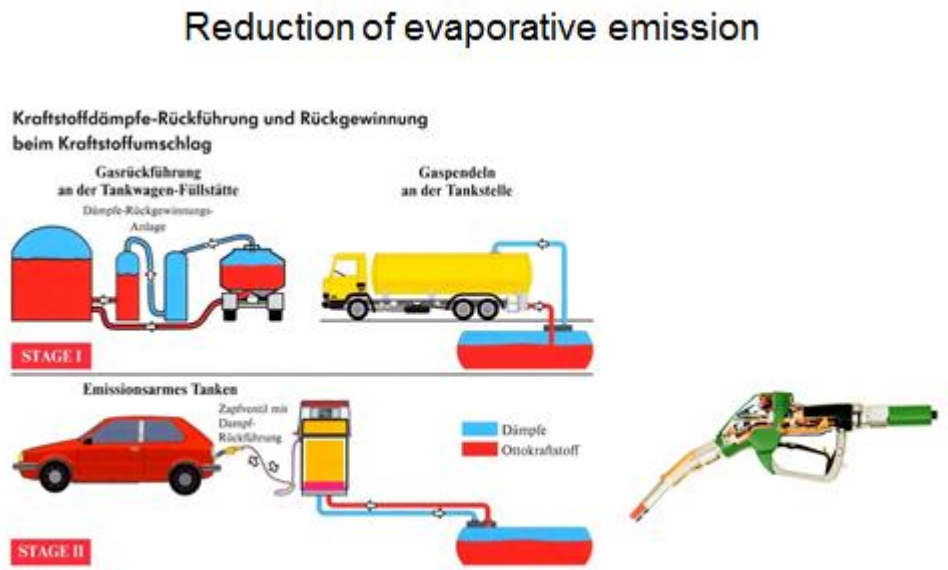


Figure 14 Reduction of evaporative emission during refuelling

Vehicle noise control in traffic is carried on the parked vehicle with the engine running at idle speed, according to ISO 5130 standard.

The traffic, especially the vehicle traffic, is the base for supply and existence of the economy and modern society and a prerequisite for a high standard of people, jobs and social security.

In parallel with the development of transport, the growing desire of individuals and society for a life oriented toward environmental requirements has been observed in the last decade and without changing the existing structures of the economy, demand and desire for mobility. Everyone wants to be mobile, but does not want to suffer the burdens arising from traffic. So, one of the primary tasks of the automotive industry is to improve the efficiency of transport systems, while minimizing burdens on the environment caused by it.

Energy consumption is one of the first criteria for assessing the ecological characteristics of individual transportation system. In the first place, for its reduction, there is ensuring its smooth traffic flow. Traffic flow often forces the driving style, in which the fuel consumption, the exhaust emissions and noise are very unfavourable (Fig. 15).

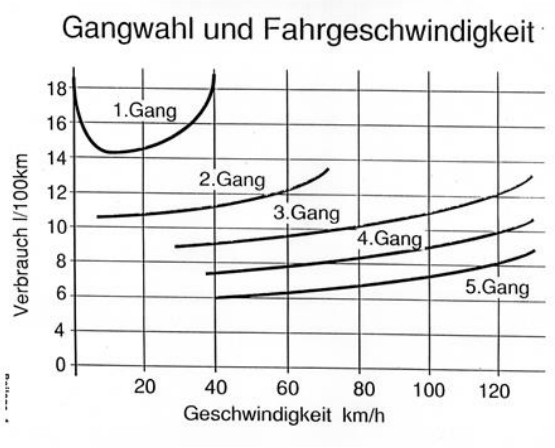


Figure 15 Influence of gear selection on fuel consumption

The lower the average speed in urban traffic is, the greater the fuel consumption and exhaust emissions are.

Prerequisite for traffic to fulfil its function is the existence of appropriate infrastructure. Traffic flow depends not only on the number of vehicles, but also on the state of the roads and on traffic organization. To organize the traffic by intelligent planning means its simultaneous environmental planning. It is often possible, for example in freight traffic, to realize the same transport capacity with much lower fuel consumption, that is with lower costs and less environmental loads (Fig. 16).

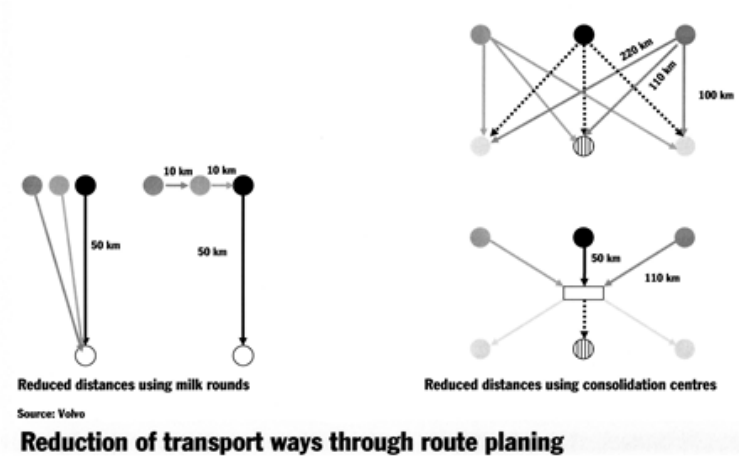


Figure 16 Reduction of transport ways through route planning

In many places, it is no longer possible to build additional traffic infrastructure. Great expectations in terms of solutions of acute traffic problems and the associated environmental loads lie in the systems of modern information and communication technology (telematics). Although this technology is still in its infancy, the following results were registered:

- reduction of the number of traffic accidents for 20 to 30%,
- 10% reduction in fuel consumption and CO2 emissions due to reduced traffic jams,
- 5% reduction in fuel consumption and CO2 emissions due to reduction of driving time in the search of target and
- 5% reduction in fuel consumption and CO2 emissions through better links between individual and public transport.

Besides all the technical improvements on the vehicle and its power unit, in the choice of vehicle size, in capacity utilization and the like, the individual driving style of each driver greatly affects the fuel consumption, exhaust emissions and vehicle noise. Modern, highly developed vehicles can develop their own features, only by their proper use. Misuse of technology can completely cancel many good vehicle qualities.

At a certain constant speed, the fuel consumption can be doubled if the gear is not well chosen. The differences in fuel consumption up to 36% are often measured on the same vehicle, in the same traffic conditions, which were caused by a variety of drivers with different driving styles (Fig. 17).

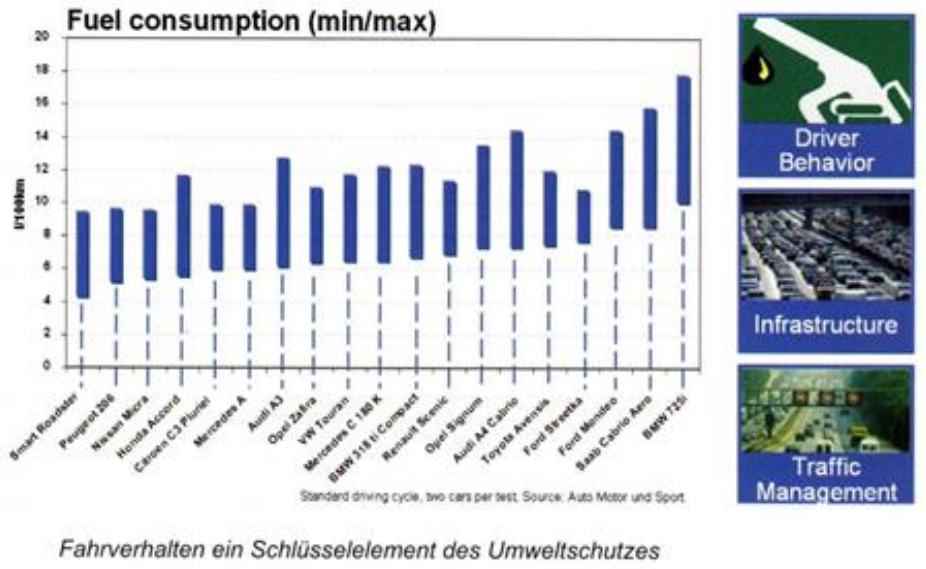


Figure 17 Driver's behaviour is a key element of environmental protection

RECYCLING

The average lifetime of passenger vehicles in the EU is around 10 to 14 years. After that, the question is what to do with the old vehicle? It consists of about 10.000 different parts and 40 different materials. The largest portion of these materials are iron and steel, light metals (Al and Mg) and plastics.

After the World War II, technologies for obtaining materials from old vehicles were developed in the world, so that the percentage of recycling amounted to about 75% of vehicle weight for a long time.

The efforts of modern society to reduce the negative impact of human activity on nature did not leave the end of product functions outside attention. In October 2000 End of life vehicle (ELV) regulation was adopted which applies to all EU member states. In accordance with this regulation, vehicle makers were required to, first provide stations for free admission of worn out end of life vehicles

Since January 1st, 2006, all new vehicles put into traffic must prove that their recycling quota amounts to 85% of vehicle weight, out of which, only 5% may be thermally utilized and 15% of vehicle weight may be disposed on landfills. Since January 1st, 2015, new vehicles must meet a quota of 95% recycling, with up to 10% of energy use.

For all vehicles produced after July 1st, 2003, law prohibits, with some exceptions, the application of lead (Pb), cadmium (Cd), mercury (Hg) and hexavalent chromium (Cr VI).

For each vehicle, there has to be a manual for dismantling the vehicle with information on the treatment of the parts and components of the vehicle. Therefore, already at the stage of defining the structure of a new vehicle, requirements on recycling are also set. "Design for recycling" is a new branch of activities of designers in the automotive industry. As over 70% of vehicle parts are produced by the supporting industries, the cooperation between vehicle manufacturers and their suppliers is very important. For that purpose, the so-called International Material Data System (IMDS) has been developed in order to

accurately describe the chemical composition of all parts of the vehicle, so the 95% quota can be met.

LIFE CYCLE ASSESSMENT

Production system of the vehicle includes its development, production, exploitation and recycling of end of life vehicles. A comprehensive instrument for assessing the environmental impact of the product throughout the whole lifetime is the ecological balance or Life Cycle Assessment (LCA). In accordance with the ISO 14000 series, LCA is defined as "the systematics in the collection and analysis of data at the input and output of materials and energy into a certain system and of their impact on the environment, which are related to the function of the product throughout the life cycle" (Fig. 17).

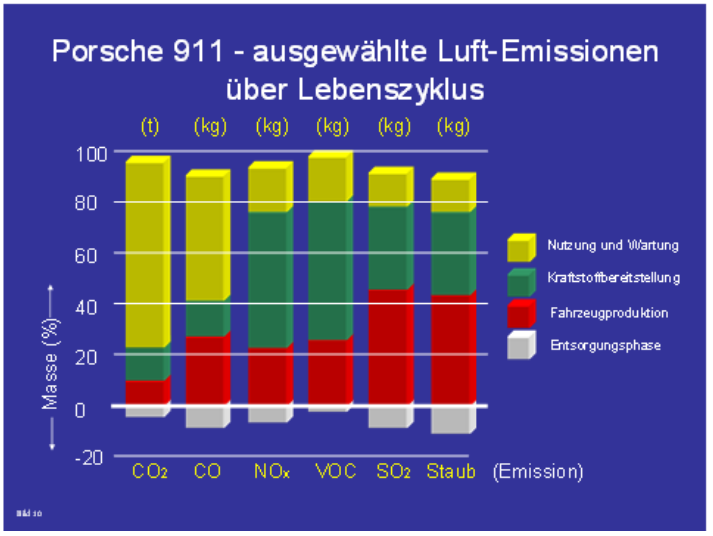


Figure 18 Life Cycle Assessment of Porsche 911

The LCA should point to ways for further improvement of the environmental characteristics of vehicles during the whole of his "lifetime". It is a new, relatively young scientific discipline, which is still in development.

PROSPECTS FOR THE FUTURE

All parameters now indicate that the vehicle will retain its primacy as a means of transport for the foreseeable future. Its replacement has not been found yet. Of course, all the demands placed before it by the increasing density of traffic, especially in large crowded cities, will still have to be met, with all the problems related to energy consumption and environmental pollution.

Question of vehicle's power unit will find its answer primarily in energy offer at the market. Predictions about the quantity of existing oil reserves do not change for decades. Even today, as well as half a century ago, it is said that they will last for another 30 to 40 years. But, regardless of the availability of the reserves, it is known that they are limited and, therefore, the search for other fuels is the constant companion of development in the automotive industry.

The intensive search for alternative vehicle power units for more than 100 years had showed that none of the proposed systems, in the sum of their properties, could compete with a four-stroke IC engine. At the beginning of the 21st century, it is considered that the IC engine will be the main power unit for vehicles in the next 20 to 30 years. The only alternative that does not replace but complements the IC engine is the so-called hybrid drive, a combination of engine drive and additional electric drive. Vehicle with pure electric drive or drive based on so-called fuel cells will not be applied in mass transport for a long time.

But, regardless of which power unit would drive the vehicles, the requirements of environmental protection will become increasingly stringent. The future power units, new materials and new fuels will also have to fulfil all environmental regulations at all stages of vehicle life cycle, from obtaining the raw materials to recycling the products. Because one thing would not change - the four elements on which the ancient world rested: air, water, earth and fire, will still remain of paramount importance for the survival of mankind.

REFERENCES

[1] Gruden, D.: Umweltschutz in der Automobilindustrie. Vieweg+Teubner Verlag, Wiesbaden, 2008

[2] Gruden, D.: Varovanje okolja v automobilni industriji. Založba Izolit. Kranj, 2011

[3] WHO – Guidelines for indoor air quality. WHO-Europe, Copenhagen, 2010

[4] MAK-und BAT-Werte Liste 2013.Deutsche Forschungsgemeinschaft. Mitteilungen 49/2013

[5] Worldwide Emission Standards and Related Regulations. Continental, March 2013

[6] Worldwide Emissions Standards. Passenger Cars and Light Duty Vehicles. Delphi, 2013/2014

[7] Umweltverträglichkeitsprüfung (UVP) – gute Aufwand-Nutzen-Bilanz. Umwelt, 5/2009

[8] EMAS – Novelle in Kraft getreten. Umwelt, 3/2010

[9] Internationales Wiener Motorensymposium. Wien, 2014

[10] 14th International Symposium, Automotive and Engine Technology. Stuttgart, 2014

[11] Gruden, D: Thermodynamischer Prozess mit isothermer Expansion. Deutsches Patentamt P 2507 142.5. 19.02.1975

[12] Gruden, D.: Combustion and Exhaust Emisssion of an Engine Using the Porsche Stratified-Charge-Chamber-System. SAE-Paper 750888

[13] Warnecke,W.: Kraftstoffe für das 21. Jahrhundert. MTZ, Oktober 2006

[14] Gruden,I. et all: Neuer 14,8-L-NFZ-Motor von Daimler für den NAFTA-Markt. MTZ 74 (2013) 12

[15] Informations- and Kommunikationstechnologien für sichere und inteligente Fahrzeuge. Kommision der EG- Gemeinschaften, Brüssel, 2009

[16] Pflieger,I.: Grundsatz Ökobilanz. CTI – Forum CO2, Sindelfingen, 2007

[17] Directive 2000/53/EC of the European Parliament on End of Life Vehicles . 8. Sept. 2000.

Intentionally blank